Analysis of Subsurface Clathrates in the Upper Crust of Titan

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Introduction

This project focuses on the analysis of subsurface clathrates in the upper crust of Titan and how they are the main source of methane production on the satellite. My task involved modifying a calorimeter to create a high pressure system which would allow me to determine various thermodynamic properties of clathrates.

Background

Titan has an atmosphere rich in methane, which should have long since been depleted unless a mechanism exists for storing this molecule below the surface. One hypothesis is that methane could be stored in the form of a clathrate hydrate, which is a structure with an ice lattice forming molecular cages in which gases are trapped. It is stable at low temperatures and over a wide range of pressures, suggesting that a clathrate hydrate may have stored methane on Titan from the beginning of its history.

Comment [MSOffice1]: This molecule instead of "these compounds"

Cryovolcanic release of methane is the most likely process for methane to enter the atmosphere. The ammonia-water mixture from cryovolcanic eruptions helps methane trapped in clathrate hydrates escape because ammonia greatly increases the melting point of water ice.

Objectives

The initial objectives of this project were to implement a high-pressure system for the calorimeter, to calibrate it, and to test it by using the well-known properties of pure CO_2 to measure the vapor-liquid equilibrium in terms of the pressure-temperature curve and determine other thermodynamic properties. Afterwards I planned to measure the phase diagram of CO_2 clathrates if time allowed.

Approach

The first major step that had to be taken was to create the high pressure system for the calorimeter. We started out with a large metal sheet that we had to cut holes in so the tubing system could be mounted on the back. The tubing system had already been created before I arrived, and I had to determine the locations where the holes needed to be drilled so the valves could fit through. Figure 1 shows an outline of the pipes for the high pressure system. The transducers are used to measure the pressure of the gas in the pipes. The gauge on the left shows the pressure of the gas inside the system, while the gauge on

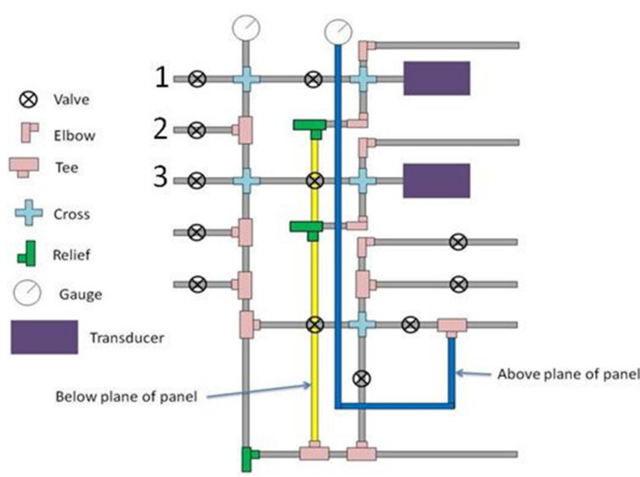

Figure 1

the right shows the vacuum pressure. Reliefs are used to vent the system if the pressure goes

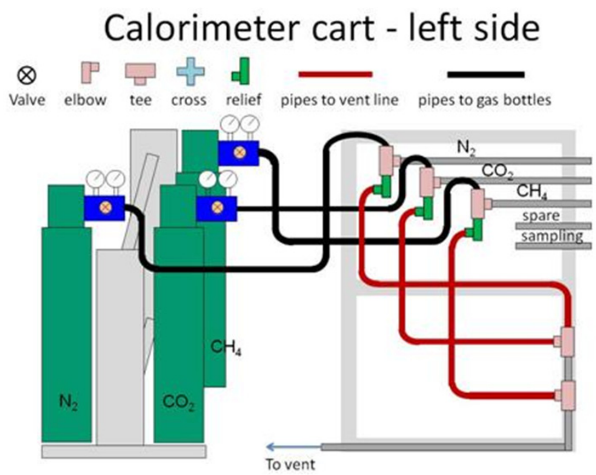

Figure 2

above 1800 psi. Once we finished drilling the holes, we attached the panel to the cart that held the calorimeter. The panel was finished and almost ready to use after a pressure gauge, a vacuum gauge, and two pressure readouts had been mounted as well. An exhaust line was added to the panel to allow us to vent out the potentially harmful gases we would be using in the calorimeter. Figure 2 shows the left side of the calorimeter cart and how the pipes attach to the different gas bottles. The N_2 line corresponds to (1) in Figure 1, the CO_2 line corresponds to (2) in Figure 1, and the CH_4 line corresponds to (3) in Figure 1. The three gases are released into the high pressure system as needed. Before the calorimeter could be used for experiments, we performed a helium leak test to see if there were any leaks in the panel.

Results

I was not able to complete all of the goals that the project had set forth when I arrived at JPL; however, I was able to achieve notable progress. The high pressure system for the calorimeter has been completed, and it has been tested and calibrated.

Discussion

Unfortunately, I was unable to perform the thermodynamic tests with the calorimeter because I ran out of time while working on the high pressure system. We encountered many unexpected difficulties while working on the high pressure system, such as having a faulty pressure gauge and reworking the clamping mechanisms for the pressure readouts and the vacuum gauge. Another item that slowed us down was locating and obtaining the software for communication between the computer the pressure readouts. Troubleshooting the leaks took a while because there were many connections on the high pressure system that were all candidates for leaks.

Conclusion

In the end, I found this project to be very beneficial because it taught me many valuable points about clathrates on Titan and how they contribute to keeping its atmosphere filled with methane. Before I came to JPL this summer, I had never heard of a clathrate, and now I am well aware of their significance on Earth and throughout the solar system, especially Titan. My work has also taught me many important engineering skills in designing and building high pressure systems, and I am now familiar with many of the companies that engineers purchase materials from, such as Swagelok, MKS, and Setaram.

Although I did not complete any thermodynamic tests with the high pressure system, I have set it up so it will be ready to use for various tests later on. Possible next steps include: 1) A few CO_2 tests to fully cover the range of pressure and temperature of the CO_2 vapor equilibrium from the triple point to the critical point, 2) A few pure CO_2 and CH_4 clathrate tests to establish the procedures to synthesize them and measure their phase diagram and properties and compare the results with expectations from various texts, and 3) Tests on CO_2, CH_4, and CH_4-CO_2 mixed clathrates in water-ammonia solutions.

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